RESEARCHES

INTO THE

IDENTITY

OF

The Existencies or Forces;

LIGHT, HEAT, ELECTRICITY, AND MAGNETISM.

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MECHANICAL ELECTRICITY.				THERMO ELECTRICITY.		VOLTAIC CONDITION, WITH ACIDS, ETC.
Metal, or Disc employed.	Tool, or Opposing Metal.	Current, and its direction, *as seen at the Galvanr.*	Simple Affinity.	Thermo electric Nature.	Currents and direction.	
BISMUTH DISC	Copper Wire	40° from the Copper towards the Bismuth	B. Electro-negative	B. Electro-negative	35° to 40° given out at its heated extremity to the Copper from its heated end	B. In Nitric acid with Platina or Copper, pos.
DITTO	Steel Tool	40° to 45° from the Tool	B. negative.	B. negative.		
DITTO	Bismuth Rod	10° to 15° from the Rod	Disc neg.	in all	cases ditto.	
DITTO	Antimony Rod	45° from the Rod	B. negative.	B. negative.	42½° towards B.	
DITTO	Silver sharpened	40° from the Silver	B. negative.	B. negative.		
DITTO	Gold	35° from the Gold	B. negative.	B. negative.		
DITTO	Lead.	27½° from the Lead	B. negative.	B. negative.		
IRON DISC	Steel Tool	10° from the Iron	I. positive.	I. positive.	7° towards the heated end.	
LARGE DITTO	Steel Tool	20° from the Tool	I. negative.	I. negative.	*	
IRON ROD	Steel File	7½° from the Iron	I. positive.	I. positive.	7° as above.	
ZINC DISC	Copper Wire	3° from the Zinc	Z. positive.	Z. positive.	2½° to 3° from the cold extremity.	In acid sulph. dilute Zinc pos.
DITTO	Sharp edge of Copper	3° from the Zinc	Z. positive.	Z. positive.	ditto	As in Electro motion.
DITTO	Turning Tool	5° (by steam power) from the Tool	Z. negative.	Z. negative.	5° The Zinc current opposed that of the Iron	In sulphuric acid, Zinc pos. Iron neg.
DITTO	Iron sharpened	4° to 5° from the Iron	Z. negative.	Z. negative.		
DITTO	Bismuth Rod	12° from the Zinc	Z. positive.			
COPPER DISC	Bismuth Rod	15° from the Copper	C. positive.	C. positive.	35° see above.	
DITTO	Rod of Zinc	2½° to 4° from the Zinc	Z. positive.	Z. robs Cpr.	2½° as above	As in Electro motion.
DITTO	Sharp Iron	8° from the Iron	C. negative.	C. negative.	5° to 7½° see above.	
DITTO	Steel Tool	2½° to 3° from the Steel	C. negative.	C. negative.		
DITTO	Copper Rod	0° simply a conductor	....	....	0° simply a conductor.	
BRASS DISC	Steel Tool	5° from the tool	....			
SILVER	Copper Disc	simply a conductor	S. positive.	S. positive.	1° to 1½° towards the heated end.	
GOLD	Ditto	0° simply a conductor	....	G. positive.	½° to 1°	
LEAD	Ditto	from the lead	....	L. negative.	2° towards its cold extremity.	

* By *first* heating the Steel in conjunction with Iron, and giving it the greater influence of the flame, the current was reversed.—Iron neg. Steel pos.

Researches into the Identity of the Existencies or Forces—Light, Heat, Electricity, and Magnetism. By John Goodman, Esq.

(Read November 3, 1846,)

On Thermo Electricity.

It was discovered some years ago by Mr. Sturgeon, that thermo Electricity does not require more than one metal for its development.

In confirming this discovery I have found that the current was developed only by the more *crystalline* metals, Bismuth, Antimony, Iron, Steel, Zinc, &c. as will appear on inspecting the accompanying Table.

I found also that each metal possessed its own distinctive and peculiar amount of current, as indicated by the galvanometer, and that, always

in the same direction: that when two opposing metals were united in producing a thermo current, the minor current would be found to neutralize the opposing current, precisely to the amount of its own powers, and with as much exactitude as if it had been done by arithmetical calculation.

Thus iron alone gave 7½° current. Conjoined with Zinc 5°; Zinc alone 2½° in the opposite direction.

It was also discovered that a minor current conjoined to one of a more powerful nature, does not generally augment, but rather diminish the amount of the latter.*

I found that the uncrystalline metals, gold, silver, copper, lead, &c. were unable to develope currents of any appreciable amount, (as seen also in the Table,) although the heating process was continued to a considerable degree of intensity, (see 37, 38.)

* It was found that the crystalline metals, Bismuth and Antimony, which form the best combination for thermo-electric purposes, are naturally mutually reciprocal metals. Bismuth negative, 45°; Antimony positive, current 22½°: and yet, conjoined, they only produced a current of 48°.

The experiments adduced show, that these latter metals may be simply regarded as conducting media to thermo Electricity, that they offer no specific resistance to the flow of current, and may, therefore, be employed either in conjunction with electro-positive, or electro-negative metals.

The results thus arrived at resemble much those evinced by the experiments of Dr. Franklin and others on the Tourmalin, in which ordinary Electricity was developed by heat alone, save that in this instance the electricity resembles the voltaic fluid, owing no doubt to the want of that complete insulation among the molecules of the metals, which is afforded by the Tourmalin.

It is remarkable that no polar fluid, or Electricity of any kind, is ever developed without the employment of a crystalline, insulating, or imperfectly conducting body. For in voltaic arrangements, *the Electrolyte is this non-conducting medium;* in the cases just cited, the Tourmalin was the intermediate polar body; in ordinary Electricity, the glass cylinder is the non-conducting body, or "Electric," and in thermo, and mechanical Electricity, (hereafter to

be mentioned,) the crystalline metals, bismuth, iron, steel, antimony, zinc, &c. are found to be the intervening polar structures, giving rise to these forms of electric fluid.

The same remarks hold good also with regard to the polar condition and *insulating* properties, (witnessed by the author,) of high pressure steam in the generation of hydro-electric, and to the polarizable quality of steel and iron in Electro magnetic, magneto Electric, and magnetic phenomena.

In contemplating the known electrical phenomena which occur by the contact of dissimilar metals, and the processes of friction, pressure, fracture, vaporization, &c. and witnessing the effects which heat thus produces upon Bismuth, &c. I devised the friction of this metal in a lathe, as a preparatory experiment to some hereinafter contained, in hopes of being able to manifest *the continuous transmission of Electricity from the one surface to the other*, as evinced by a current passing through the galvanometer from or towards the other extremities of the metals employed. This, to my mind, would evince the *origin of radiant* heat, the *result of friction*, in the me-

chanical processes—drilling, turning, filing, &c.—and which, on its discovery, I named "*Mechanical Electricity*."

In the printed report of the British Association for 1845, which met at Cambridge, I find that M. Paul Erman, of Berlin, presented a paper, containing one or two experiments of a somewhat similar nature to the Association, but of which I was not aware until the publication of the report, and the completion of many of my experiments.

April 2, 1846, I made the following experiment:

Upon a mandril of copper, a cylinder of Bismuth was cast. One end of the mandril was fixed in dry wood, and arranged in a turning lathe. The other revolved against the point of the "following up head stock," as is usual. The surface of the cylinder or disc was turned smooth, the mandril having been previously soldered to the Bismuth, so as to insure full metallic communication.

Instead of a metal rest, a wood one was now used, and afterwards a small piece of wood placed under the ordinary rest; to insulate this, and the

tool from the other portion of the lathe, was found to be *all that is necessary* in these experiments. A spring of brass wire was made to press firmly against the turning mandril, so as to ensure metallic contact; and its other extremity was in communication with the northern extremity of the galvanometer.*

In the following experiments, the direction of the current is simply stated, *as seen at the galvanometer*, which will be found, in all cases, to be the reverse of what takes place between the opposing metals. Thus, in the experiments in which *the zinc robs the copper*, as seen at the galvanometer, the current is progressing *towards the copper*.—(See 31, &c.) And yet the actual transfer at the surfaces is from the copper to the zinc.

Exp. 21. On applying the smooth surface of the end of a piece of *thick rod copper* to the turned surface of the cylinder, producing friction, a current was observed from the copper towards

* The Galvanometer, in these experiments, was not of the highest sensibility. It consisted of forty-six turns of copper wire, the $\frac{1}{25}$ of an inch in diameter. The needle was single, and had therefore a northern tendency to counteract.

the Bismuth. The rod copper was soldered to a wire in connexion with the southern extremity of the galvanometer.

Exp. 22. By accident the rod copper was torn away, and I applied merely the extremity of the connecting wire against the revolving cylinder. The galvanometer was deflected many degress, and considerably more *than by the friction with the larger surface. A large surface appeared to induce complex results, and to destroy elementary or simple indications.*

Exp. 23. By means of a set screw connected the galvanometer S wire to a turning tool, and slightly turning or shaving off ribbons of Bismuth, a considerable current was indicated *from the tool towards the Bismuth.* This experiment with the Bismuth disc and steel tool was afterwards repeated by steam power,—current 40 to 45° constant, vibrated to 80° or 90° at first.

Exp. 24. With a Bismuth rod against the Bismuth cylinder, a current of 4° and afterwards of 10° to 15° towards the cylinder was observed.*

* It is here seen that a preponderance is given in favour of the rod or tool, both metals being alike the rod is positive the disc negative.

Exp. 25. The Bismuth disc and an antimony rod gave a current of 45° in the usual direction for Bismuth—the antimony robbing the Bismuth. Antimony positive: Bismuth negative.

Exp. 26. Silver with Bismuth 40°. The usual Bismuth current.

Exp. 27. Gold with Bismuth 35°. The usual Bismuth current.

Exp. 28. Lead with Bismuth 27½°. The usual Bismuth current from the lead to the Bismuth.

Exp. 29. *With an iron disc*, rotating under similar conditions, I obtained, by a turning tool of steel, *a current of* 10°, *from the iron towards the tool.*

I tested the galvanometer by a voltaic pair, to see the direction of the current, and found the direction as stated to correspond.

I repeated afterwards the same experiment, by steam power, with a much larger cylinder of cast iron, apparently harder than before, and the needle vibrated from 15° to 30°, stationary at

20°; the current, in that instance, *from the tool towards the disc*, tested by voltaic pair.

Exp. 30. *With a zinc disc* and steel tool, at first no certain indication of current. Repeated afterwards, with and without steam power, current 3°, and afterwards 5°, constant, from the tool towards the zinc.

Exp. 31. With the extremity of the copper connecting wire, current $2\frac{1}{2}$° from the zinc towards the wire. Repeated with steam power, 3° towards the copper.

May 1st, 1846. With a sharp cutting edge of copper against the zinc disc, 3° to 5° towards the copper. These experiments *correspond with the phenomena of electro-motion*—zinc robbing copper.

Exp. 32. With a Bismuth rod against the zinc cylinder, a current of 12° was evinced from the zinc towards the Bismuth.

Exp. 33. With a piece of iron sharpened, current 4° to 5° from the iron towards the zinc, iron positive, zinc negative.

Exp. 34. May 2. *A copper disc* rubbed by a rod of Bismuth, current produced vibrating to 30° stationary at 15° *towards the Bismuth from the copper.*

Exp. 35. *A rod of zinc* against the same copper the edges of the disc being made sharp, 2½° towards the copper, with a good cutting edge, 4° constant. The zinc by this means being well cut. Repeated 4°. Zinc robbing copper as in Exp. 31.

Exp. 36. A piece of iron made sharp with filing, when used with a large copper disc, 3½ inches in diameter, gave a current of 8° stationary, while the edge remained good and removed shavings, from the iron towards the copper, iron positive.

Exp. 37. Employed a piece of rod *copper*, in friction against the revolving *copper* disc, and not the least indication of current was observed.

Exp. 38. Silver thus employed against the copper dise, gave a slight current of 1° from the silver towards the disc.

Exp. 39. With a steel tool, a constant current of 2½° *towards the copper.*

EXP. 40. A brass rod turning instead of a disc, and steel tool, current 5° from the tool towards the brass.

MAGNETISM.

EXP. 41. By filing iron with a steel file, a current of $7\frac{1}{2}°$ is produced, from the iron towards the file, and the two metallic bodies become oppositely magnetic, as shown by the following experiments.

The steel surface becomes positive, and the iron negative, which are electro polar conditions.

It will be immediately seen, that not only does the friction of a file upon a piece of soft iron induce two oppositely electrical conditions of surface, but that this *electrical state is also a truly magnetic condition*, and offers an explanation how, or *in what manner the various mechanical operations, screw tapping, drilling, filing, &c. evince magnetic phenomena.* An attempt to establish the opinion of magnetism being a *static electro polar condition*, was by the author of this paper brought forward, and published in the Report of the British Association, for 1842, page 17.

Exp. Having selected a steel file and piece of fine iron wire, free from magnetic polarity, I proceeded to draw the file several times over the surface of the wire, when by holding them on each side the north-pole of a suspended magnetic needle, it was found that the wire attracted, and the file repelled this pole with considerable force.

Exp. A new file attracted both poles of a magnetic needle, or was unmagnetic. A piece of iron wire slightly *repelled* the pole. After rubbing the wire along its surface, and holding the wire on one side of the north-pole, and the file on other, the needle was *attracted by the wire, and repelled by the file.*

Exp. A new file attracted the north-pole of a magnetic needle 10°, a piece of iron wire repelled the same. After filing the same, and placing this pole of the needle between them, the file repelled, and the wire attracted the needle. This experiment was repeated with the same result.

A thick file, and a thick piece of soft iron did not produce any change, the process not

being sufficiently powerful to induce magnetic polarity in any considerable mass of metal.*

Exp. Another file was neutral, rather attractive. The repulsive end of a piece of magnetic iron wire was employed. After filing briskly around the surface of its extremity, *the file repelled*, and the *wire attracted* the north-pole.

Exp. Took the opposite extremities of the file and wire, the wire repelled, the file attracted, but on rubbing them together, an instant change took place. *The file repelled, and the wire attracted the needle.*

Repeated with the same results. These operations were performed when the metals pointed southward. It was discovered, however, that an opposite result took place when the filing was performed towards the north. The file then attracted and the wire repelled the north-pole; but the evinced trifling difference of affinity between iron and steel, as shown in (15) may tend

* The finer the materials employed the more highly developed were the magnetic effects, and on this account iron *wire* was used.

to produce this uncertainty, which subjects them to the government of the earth's polarity.

Is the current induced by mechanical operations, simply thermo Electric or not?

Exp. 42. Immersed the lower half of the Bismuth cylinder in water at 55°. By turning it with a steel tool about one minute, (the water revolving around the cylinder the whole period,) a current was constantly maintained, at length from 35° to 40°, fine turnings being produced.

The water, 9 oz. and 2 drs. in which the Bismuth disc was immersed, and which would derive the principal part of the heat from the whole process, being heated only to 57° or 2°,* and the tool immersed in a like quantity of water, was found to increase it only half a degree.

Exp. 43. A conducting wire, made to press against the revolving Bismuth disc slightly,

* Observe, the *turnings alone* which were made, would, as will be hereafter shown, heat the water nearly to this amount, and the *tool* would in this instance heat the water more than the disc. Therefore the heat derived from the disc would be less than ½°.

produced a current of $2\frac{1}{2}°$ to 5°. But on using a disconnected turning tool to the same side, and near the wire, the current was still $2\frac{1}{2}°$ to 5°; and yet the tool could have induced a current of 30° or 40°. On increasing the pressure of the wire against the cylinder, current 6° to 9°. On using the turning tool as before, no increase of current could be perceived. Yet, on applying a lighted taper at the junction of the wire to the cylinder, current 35°.

The turning tool does not, therefore, *augment the heat of surface of the disc*, so as by heat to produce a current of thermo-electricity.

Exp. 44. Attached the two galvanometer wires to the piece of Bismuth used in the experiments for the production of thermo electricity, one at each end. Rubbed *one extremity of the Bismuth* with force against the revolving copper disc, for one minute, and yet *no current* was indicated, which would have been the case, if the heat developed by friction in these cases had been the source of development of the fluid. For instantly on applying the *same end to the flame of a spirit lamp*, the galvanometer began to deflect. Repeated the experiment with like results. And on

removing the wire at the end of the Bismuth, next to the copper disc, and attaching it to the spring which connected the mandril with the galvanometer, for mechanical Electricity, a current *was instantly produced by the same friction.* Repeated, and with like results.*

Exp. 45. Repeated a similar experiment with iron. The sharp iron of exp. 36, was attached to the two galvanometer wires, one at each end. On turning with its sharp extremity, the copper disc for some time, which produced an instantaneous current in exp. 36, no deviation of the needle was at all observed. But by holding the same end of the iron for a few moments in the spirit flame, a constant deviation commenced, which gradually progressed to $7\frac{1}{2}°$.

Repeated the experiment with like results. Yet, when the end adjoining the disc was disconnected, and attached to the spring in contact with the mandril, i. e. *the ordinary connexion for mechanical Electricity,* being made (as in 36) *an instantaneous current of* 8° (*stationary*)

* The metals here employed are the crystalline, which have been shown to be the only bodies evolving the phenomena, copper being only a simple conducting body.

was the result. Thus it is seen, that with the *same heat developed* in each case, by the mechanical arrangement, is given an immediate current, which heat will not give current at all by the thermo Electric process, and it is therefore evident *that thermo and mechanical Electricity are not derived from the same source.*

These experiments appear very decisive. The fact of the current invariably *pursuing the course of that in electro motion, or contact of dissimilar metals,* in all cases where metals illustrative of this phenomenon are employed, speaks in favour of the dissimilarity of the source of these two modifications.

It is also to be remarked here, that if mechanical Electricity were the result of the heat applied to the extremity of the metal, *the friction of flat surfaces, which is known to produce much more heat than simply cutting or turning with a sharp edge,* would produce the greatest deflection of the needle; but by this means it is found, that none, or scarcely any current is developed, even with a disc of Bismuth. (See 22, 23.)

Exp. 46. Is mechanical or thermo Electricity

conductible by water? A rod of Bismuth was arranged for thermo Electricity in this experiment, and the voltaic decomposition apparatus was employed, and it was discovered that the thermo Electric current is utterly *inconductible by water or acidulated* water; the heat was carried on to fusion, but the galvanometer did not deflect in any appreciable manner. It is also inconductible by a strong solution of sulphate of copper.

Exp. 47. The thermo Electric current from Bismuth passed through a *large piece of Bismuth* deflecting the galvanometer gradually up to 15°, by the steady heat of a spirit lamp.

Exp. 48. Mechanical Electricity is not conducted at all by *solution of sulphate of copper.*

Exp. 49 And is also *inconductible by acidulated water*, in the ordinary decomposition apparatus.

Exp. 50. But is readily transmitted by an intervening *piece of Bismuth*, of equal temperature.

Remarks.

The *direction* of the current from every individual metal, and from one metal relatively with another, is at all times *invariable*, both in mechanical and thermo Electricity.

The *quantity of force* circulating through the galvanometer, and proceeding from any given metal or specific pair of metals, is constantly about the same in amount, proportional to the intensity of the developing process, in both modifications. Each metal *evinces an amount* of force *comparatively proportional* with that of every other metal employed, both in the mechanical and in the thermo Electricity.